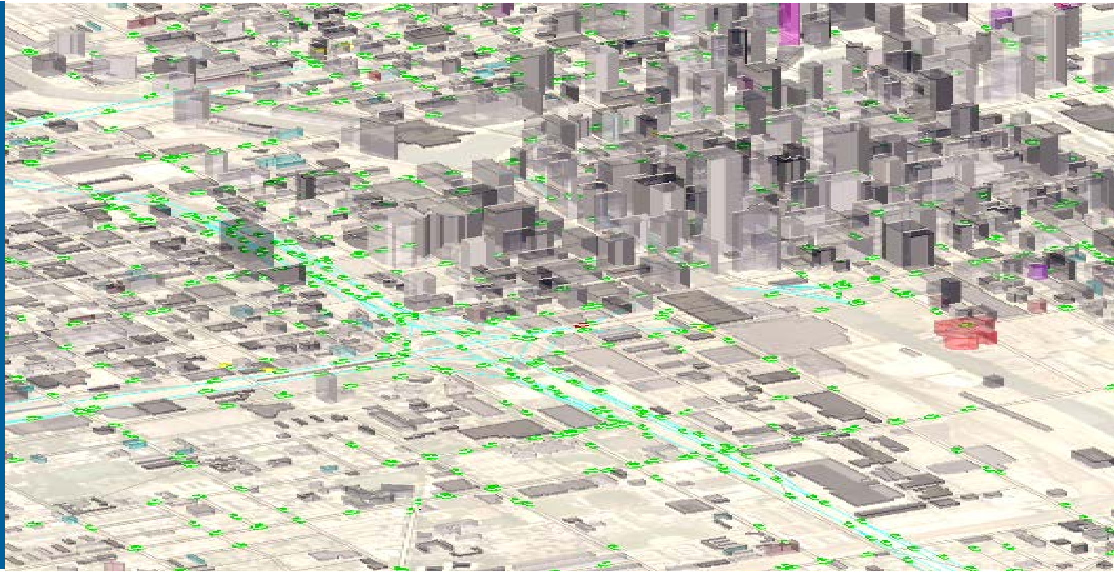
PROJECT ID # VAN035

ASSESSING VEHICLE TECHNOLOGIES BENEFITS IN A TRANSPORTATION ENERGY ECOSYSTEM



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Annual Merit Review 2020, Washington DC

PROJECT OVERVIEW

Timeline	Barriers*
Start date : Sep 2019 End date : Aug 2022 Percent complete : 15%	• Risk aversion • Constant advances in technology • Cost • Computational models, design, and simulation methodologies *from 2011-2015 VTP MYPP
Budget	**Partners**
FY 20 : $300k Percent utilized : 40% Total Project : $900K	• Vehicle Technologies Office • NREL (EVI-Pro) • ORNL (MA3T)

RELEVANCE

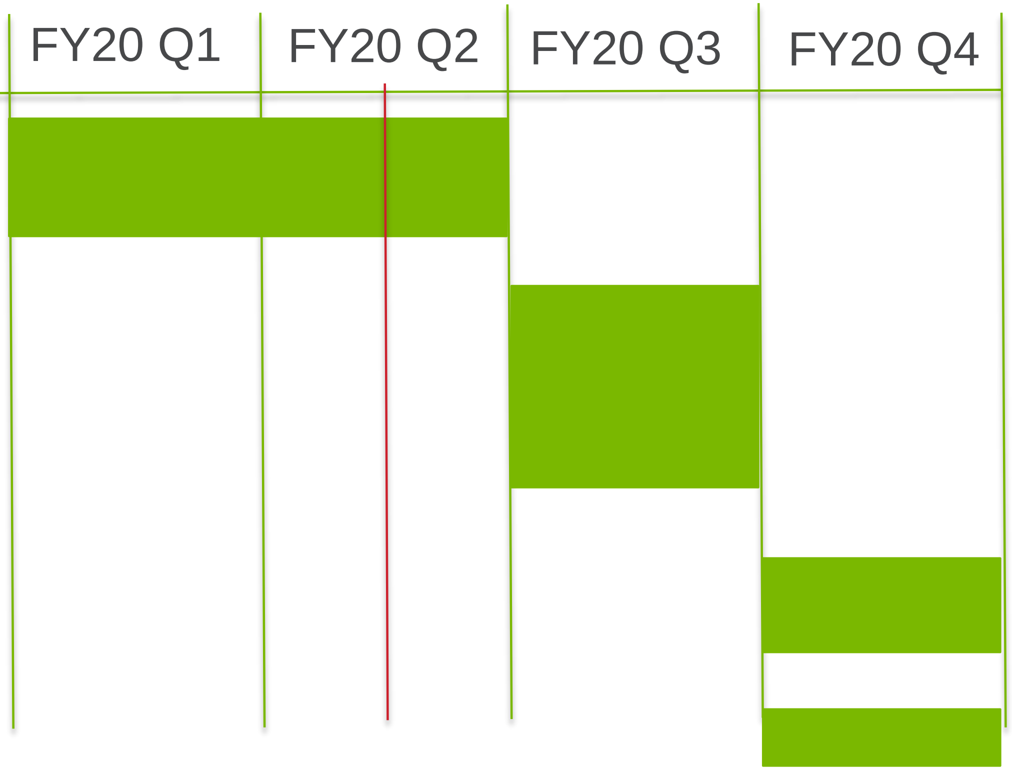
What are the VTO technologies impact across a wide range of real world usage (e.g., different Vehicle Miles Traveled) and modes (e.g., personal vs TNC) across an entire metropolitan area?

- VTO technology targets benefits have historically been assessed for energy consumption and cost benefit using US standard drive cycles such as FTP75
- How does VTO technology impacts vehicle energy consumption, cost, xEV market penetration, number and type of charging stations across an entire metropolitan area for different vehicle classes (Inc. medium and heavy duty), modes (e.g., TNC, transit) and timeframes?
- How do the results compare with the historical methodology?

MILESTONES

Activities

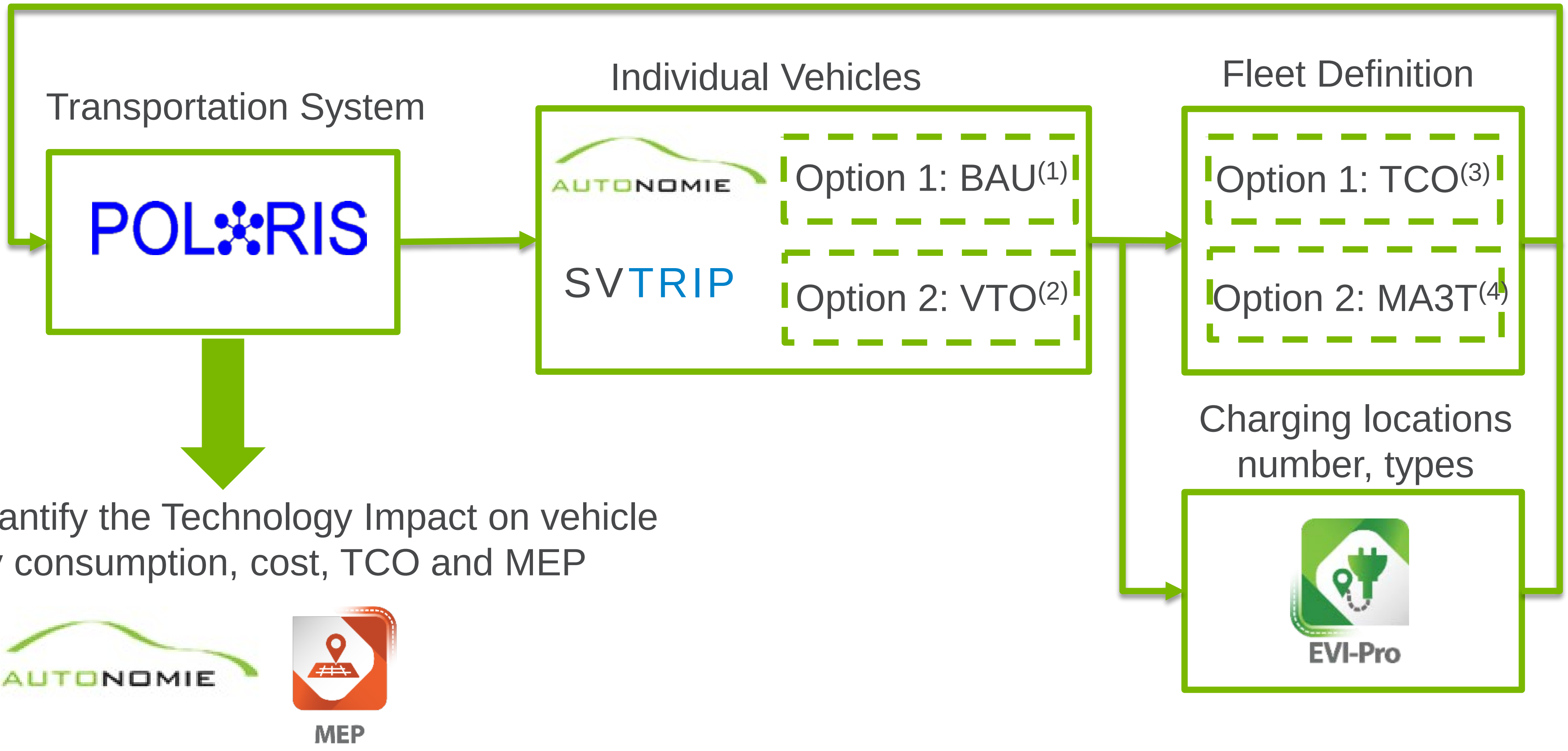
- Results quantifying VTO benefits across different timeframes (current environment)
- Summarize MEP and EVI-Pro calculations for the initial set of runs in the ANL-led POLARIS based benefits evaluation task
- Report describing differences between US standard cycles and transportation system benefits
- Report quantifying VTO impact on CAVs benefits



APPROACH

System level analysis using multiple tools integrated into a workflow

Step 1: Define the Fleet Composition & Charging Station Locations

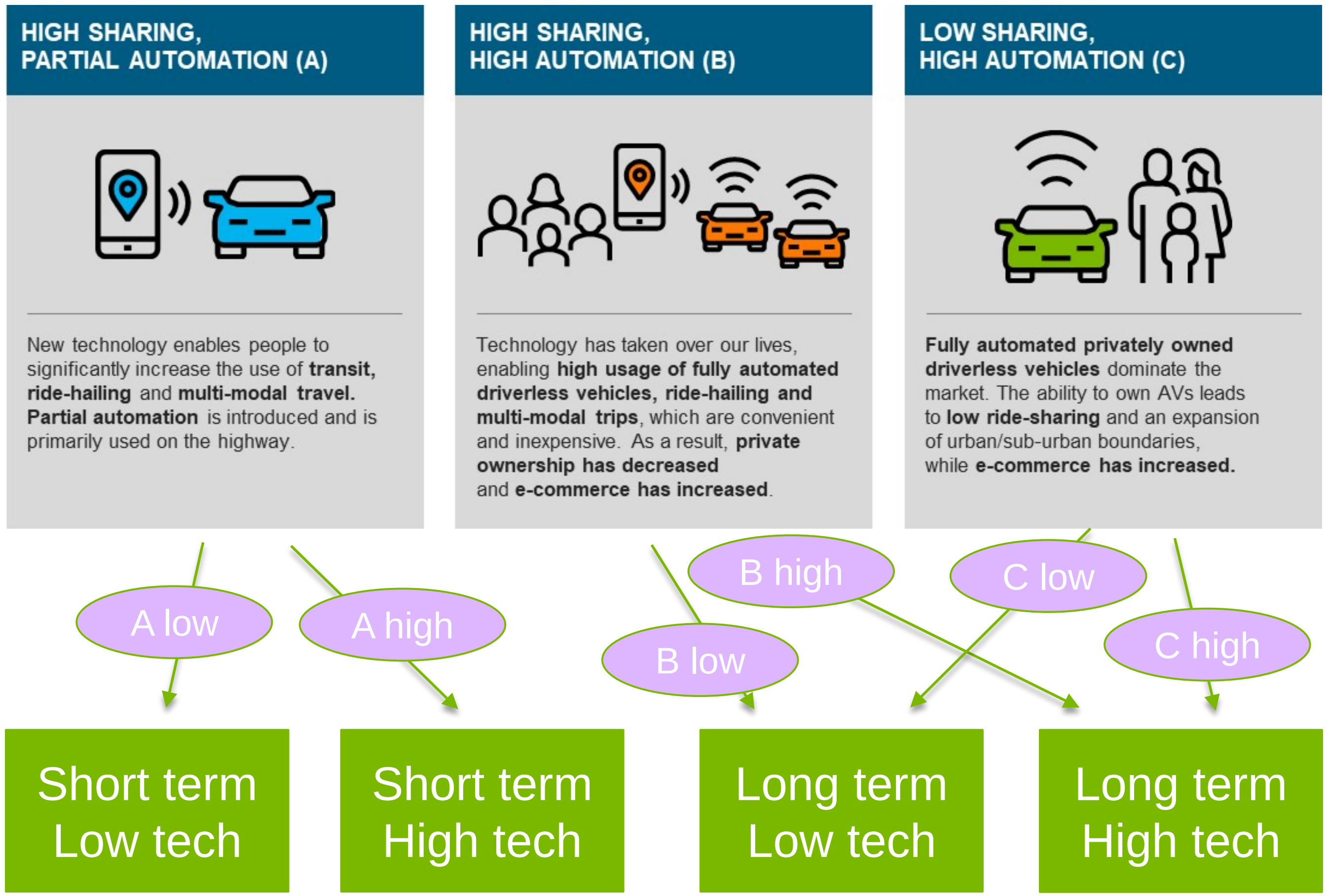


(1)Business As Usual (2)Vehicle Technologies Office (3)Total Cost of Ownership (4) Market Acceptance of Advanced Automotive Technologies Model

APPROACH

7 scenarios considered

- A baseline scenario is defined representing today's transportation system and technology ➡ 1 case
- 6 future combinations of scenarios and technologies ➡ 6 cases
- "Low tech" assumes limited investment in R&D or business as usual
- "High tech" assumes a future where high level of investments leads to significant improvement in vehicle technology as defined by the VTO targets.



Vehicle Technologies

APPROACH

For each scenario and vehicle, the energy consumption and total cost of ownership (TCO) are calculated with 5 different powertrains

- Vehicle class distribution is not affected, only powertrain is changed
- 5 powertrains
  - Conventional
  - BISG (start/stop system)
  - HEV (split hybrid architecture)
  - PHEV (50 mile range extender)
  - BEV (200 mile range)
- TCO assumptions
  - Daily miles for each vehicle is scaled up so that on average vehicles drive 14,000 miles per year
  - Energy costs are calculated over a 12 year period (4% discount rate), using gasoline and electricity cost prediction per IEA.

		Scenarios						
		Base	A low	A high	B low	B high	C low	C high
Powertrains	Conventional	✓	✓	✓	✓	✓	✓	✓
	BISG	✓	✓	✓	✓	✓	✓	✓
	HEV	✓	✓	✓	✓	✓	✓	✓
	PHEV	✓	✓	✓	✓	✓	✓	✓
	BEV	✓	✓	✓	✓	✓	✓	✓

- 35 cases simulated
- For each scenario and vehicle, the powertrain with the lowest TCO is selected

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

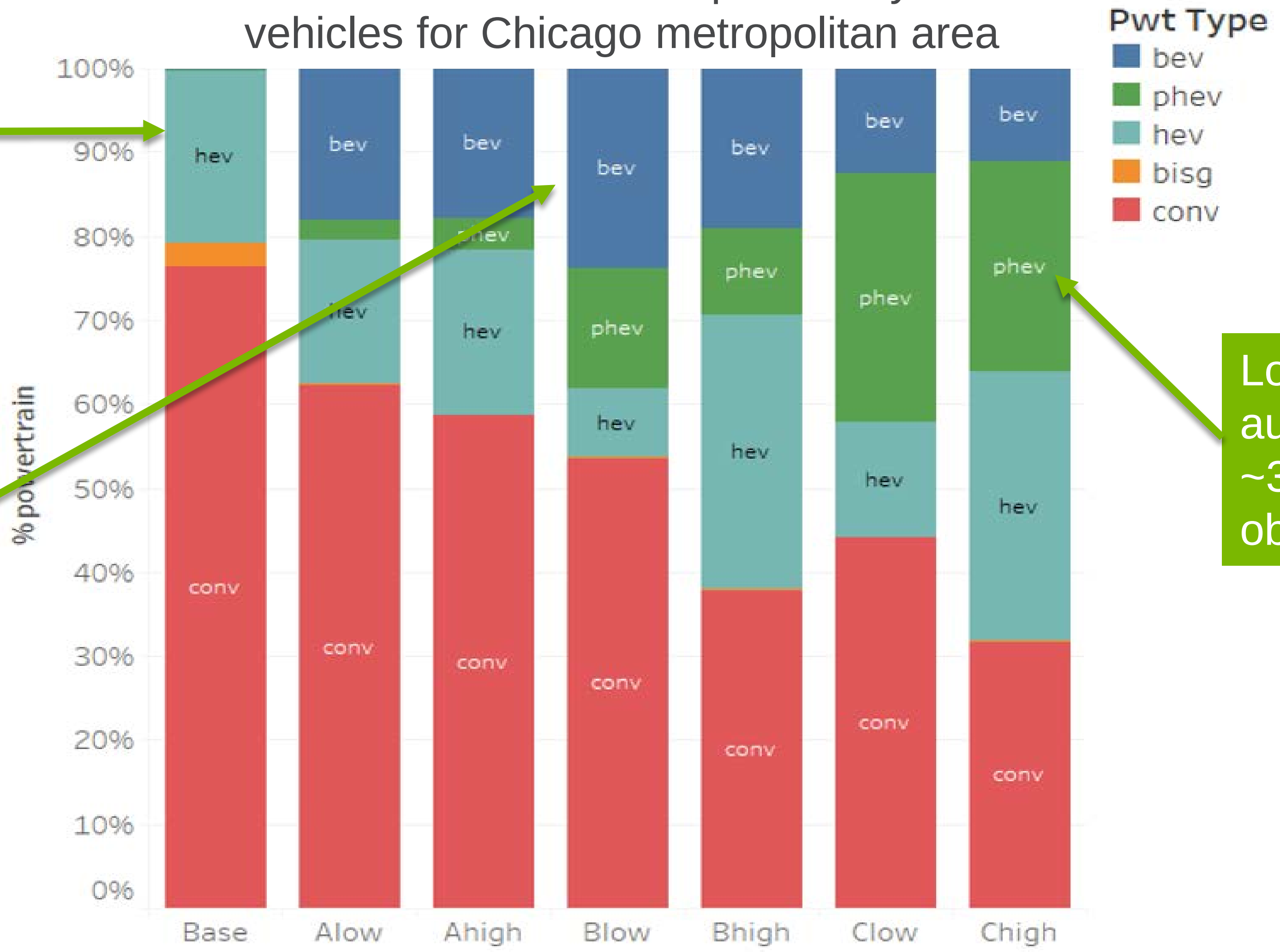
BASED ON TCO, ELECTRIFIED POWERTRAINS ARE COMPETITIVE IN FUTURE SCENARIOS FOR PRIVATELY OWNED VEHICLES

Percentage of powertrain providing the lowest TCO for each scenario for personally owned vehicles for Chicago metropolitan area

Currently, HEV account for ~20% of the fleet

High sharing, high automation scenario B, ~20% of lowest TCO is obtained with BEV

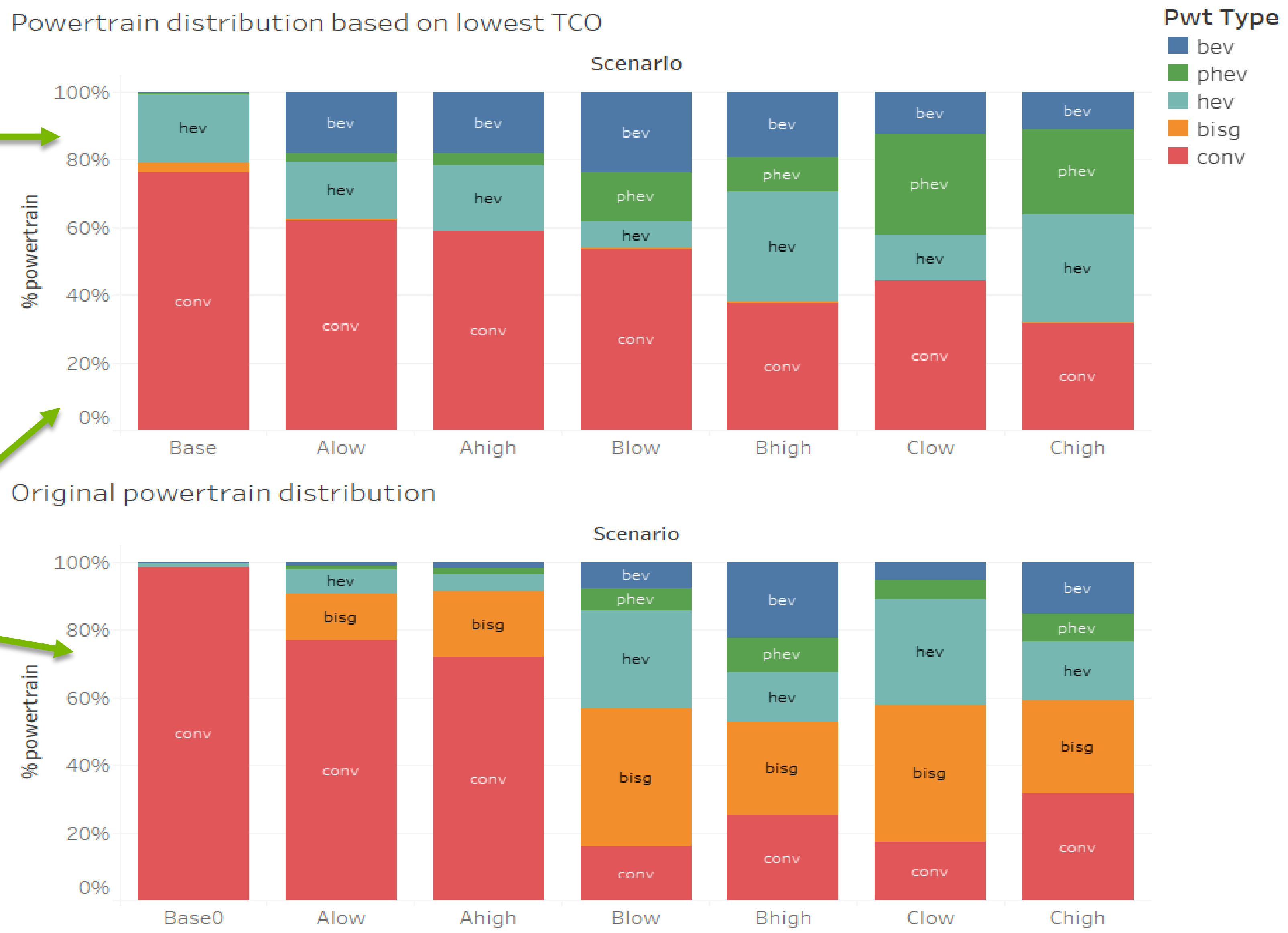
Low sharing, high automation scenario C, ~30% of lowest TCO is obtained with PHEV



THE FLEET DISTRIBUTION BASED ON TCO INCLUDES A HIGHER PERCENTAGE OF XEVS COMPARED TO THE INITIAL SMART SCENARIOS

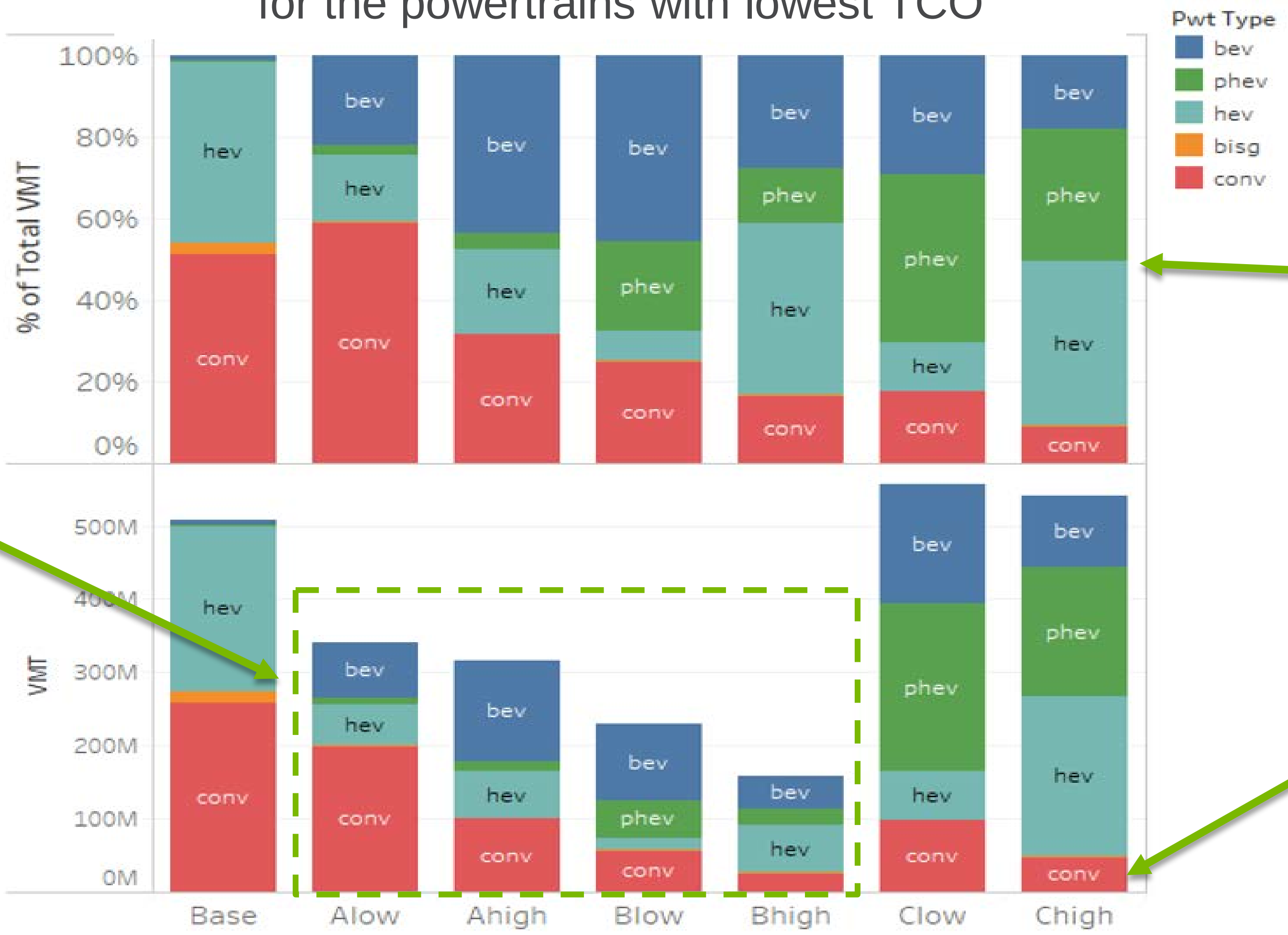
xEV shares increase

Conventional powertrain represents a lower share of the fleet when solely considering TCO



ELECTRIFIED POWERTRAINS HAVE HIGHER VMT THAN CONVENTIONAL POWERTRAINS (PRIVATELY OWNED VEHICLES ONLY)

Aggregate VMT (absolute and as a percentage)
for the powertrains with lowest TCO

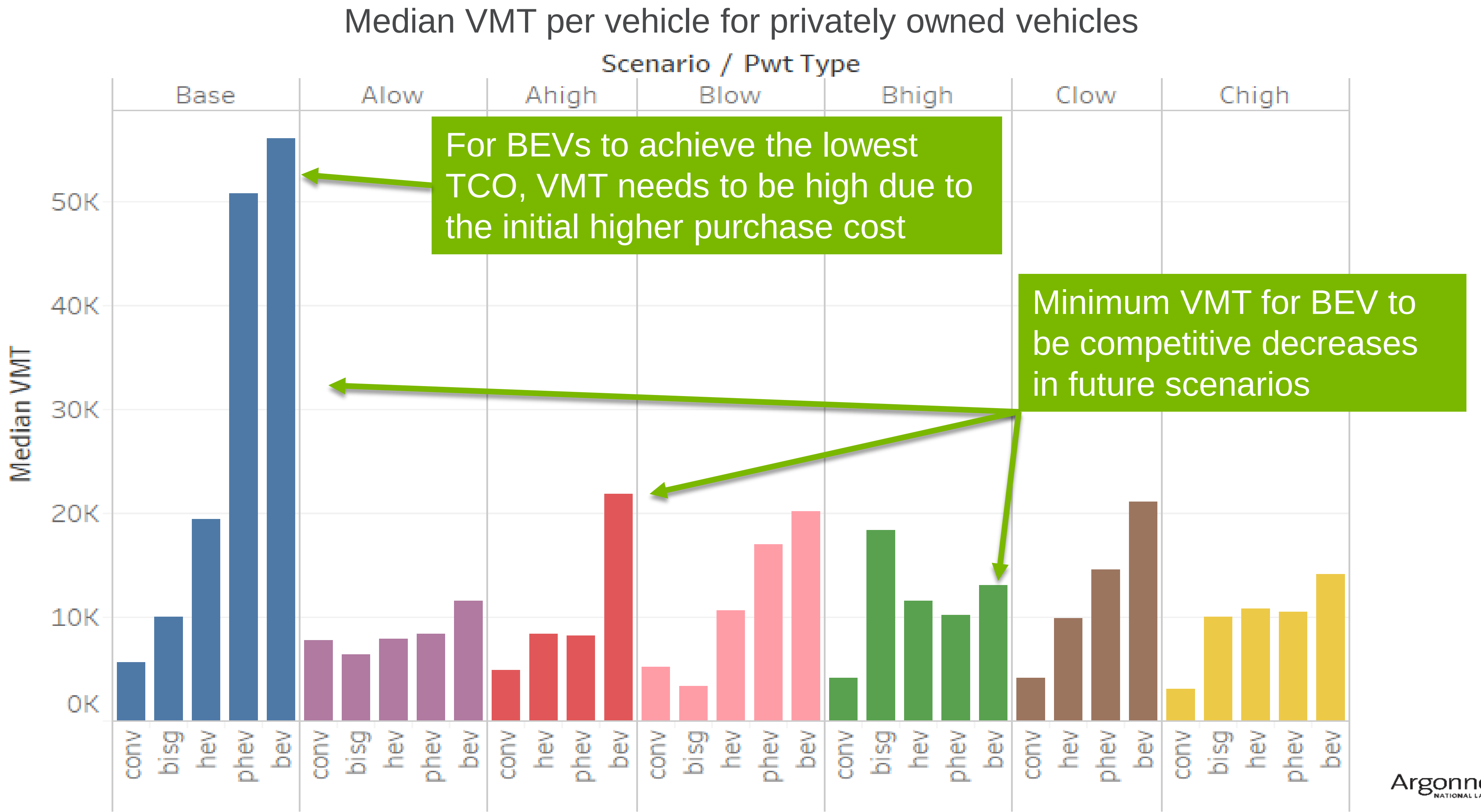


Privately owned vehicles VMT decreases due to transportation mode change

In scenarios C, PHEV and HEV make up a high percentage of the overall VMT.

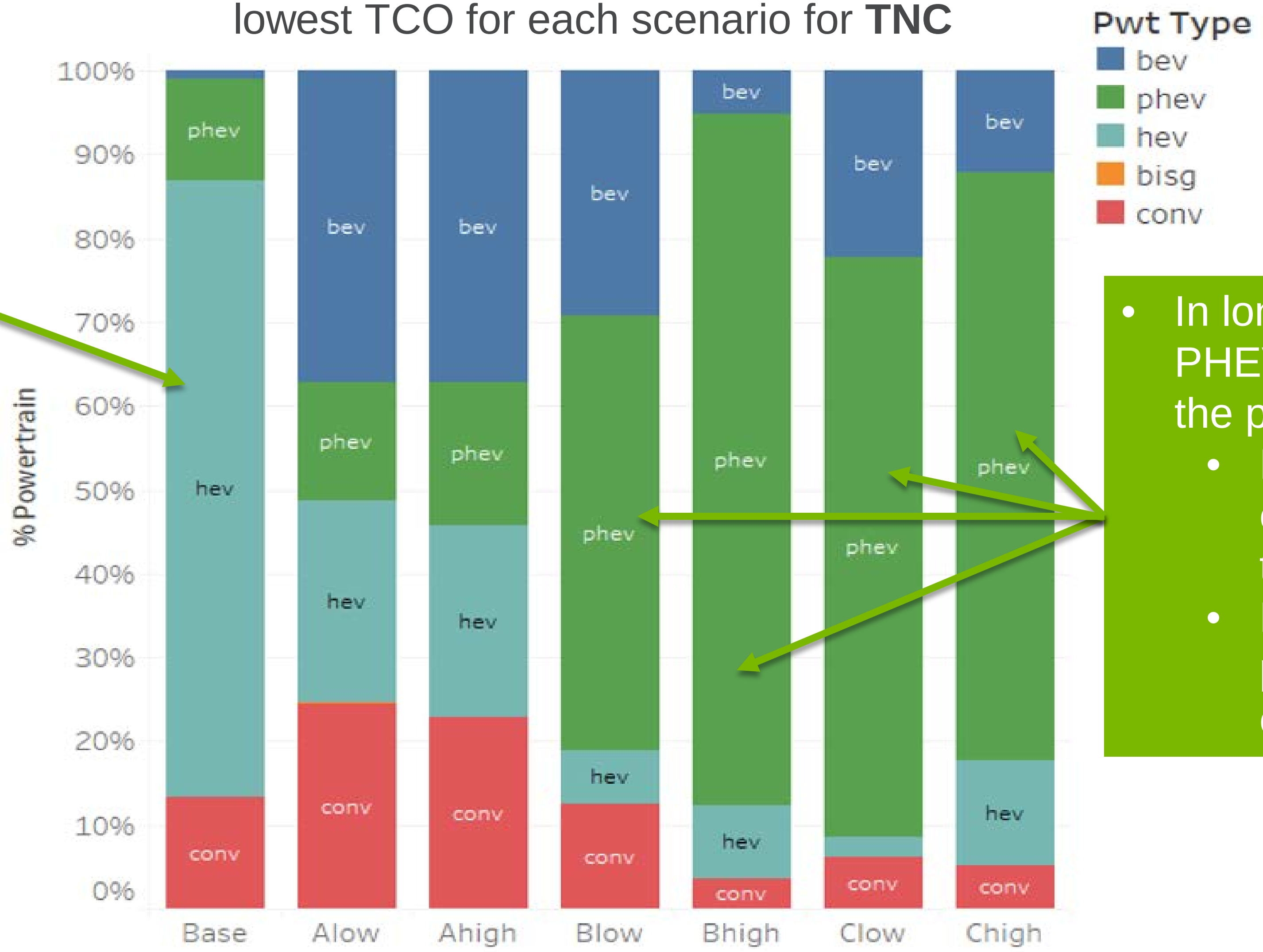
While the share of conventional powertrains in Chigh is relatively high at 30% (previous slides), the VMT share is less than 10%.

THE HIGHER THE VMT, THE HIGHER THE LIKELIHOOD FOR VEHICLES TO BE ELECTRIFIED



BASED ON TCO, THE CASE FOR ELECTRIFICATION IS EVEN HIGHER FOR TNC THAN IT IS FOR PRIVATELY OWNED VEHICLES

Percentage of powertrain that provides the lowest TCO for each scenario for **TNC**



Today, HEVs provide the lowest TCO

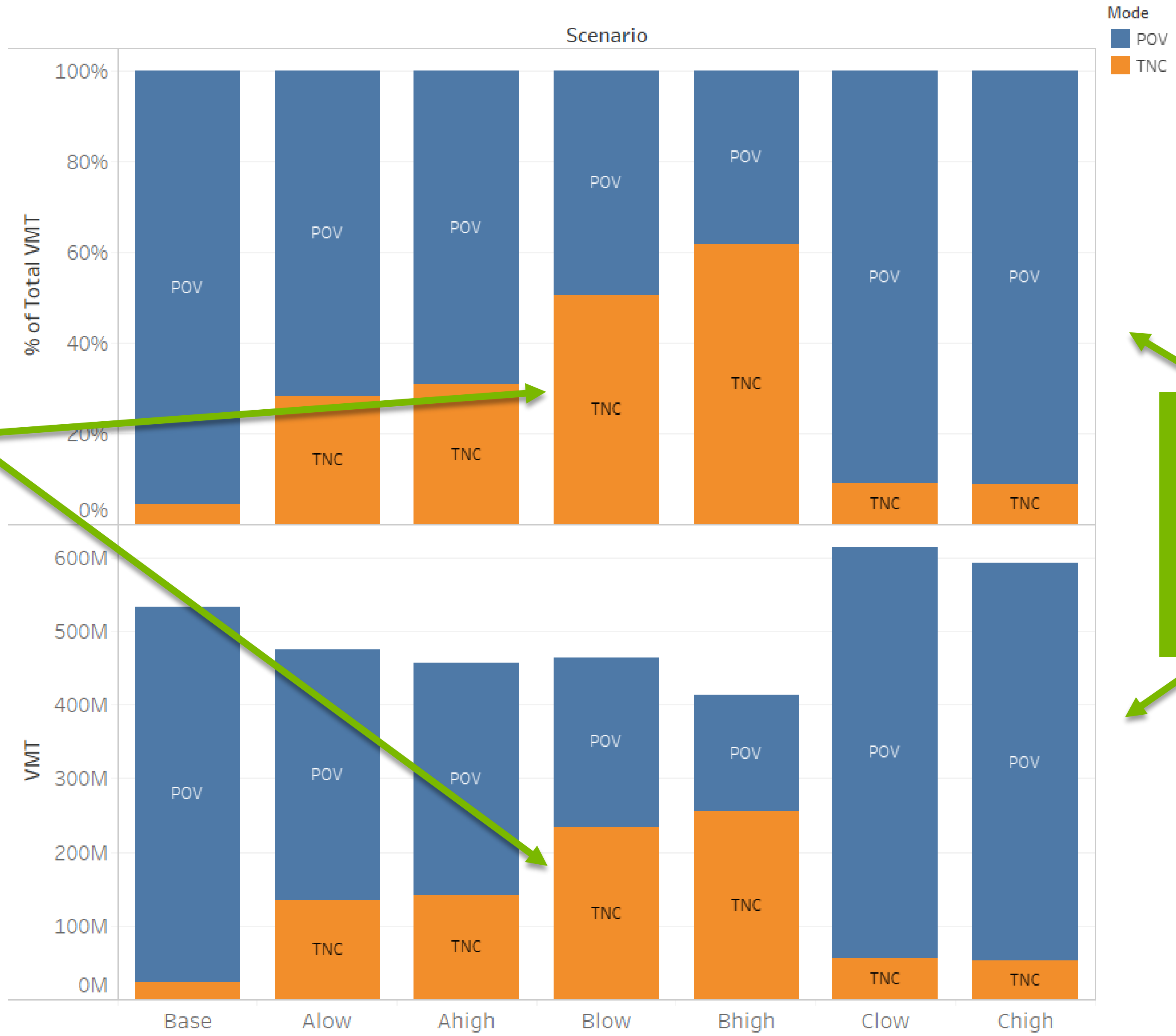
- In long term scenarios, PHEV powertrain become the powertrain of choice.
  - PHEV have a lower energy cost compared to conventional
  - PHEV have a lower purchase price compared to BEV

PHEV AND BEV REPRESENT THE MAJOR SHARE OF VMT FOR TNC

Aggregate VMT (absolute and as a percentage)
for the powertrains with lowest TCO for **TNC**

TNC VMT significantly increases in scenarios A and B (high sharing scenarios)

THE VMT SHARES OF PRIVATELY OWNED VEHICLES (POV) AND TNC VARIES SIGNIFICANTLY BETWEEN SCENARIOS

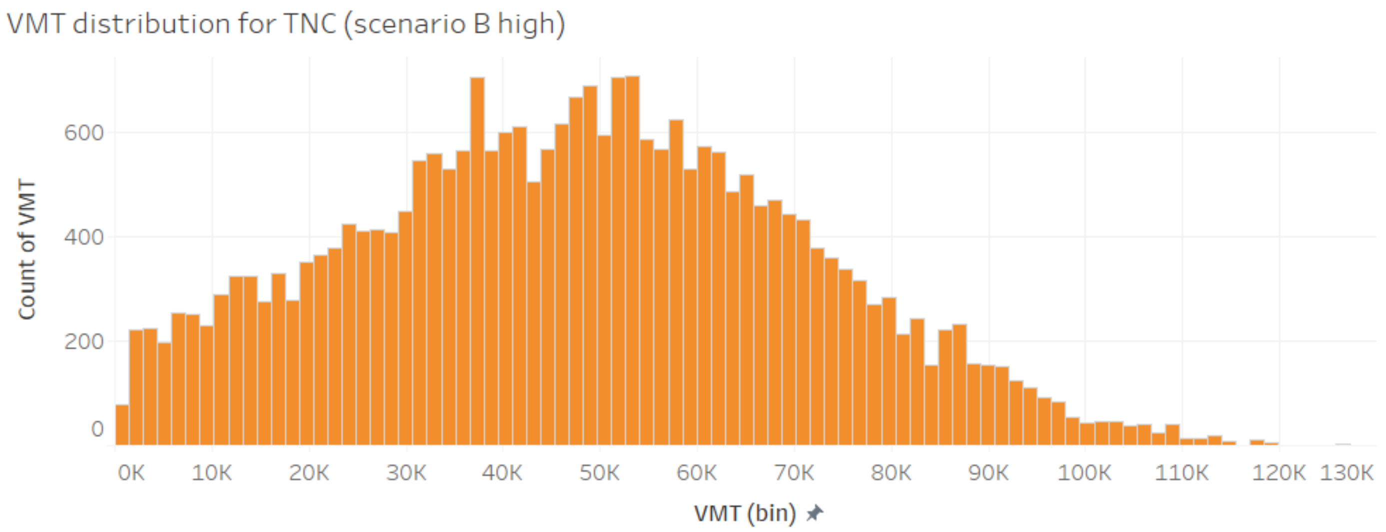


In scenario B, ride sharing has grown tremendously and TNC represents 50% of VMT

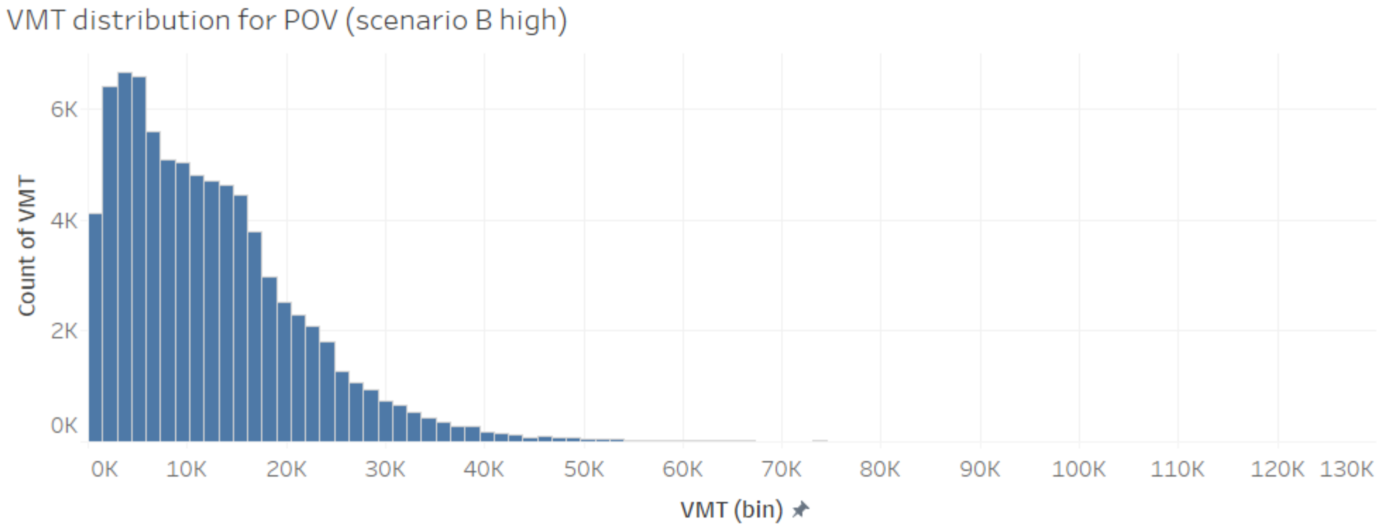
In scenario C, technology remains affordable and hence private ownership dominates

USING A LARGE SCALE TRANSPORTATION SYSTEM MODEL ALLOWS TAKING INTO CONSIDERATION THE REALITY OF VMT VARIATIONS AMONG HOUSEHOLDS

TNC vehicles drive more when compared to POV



At the aggregate level, vehicles drive 14,000 miles on average per year

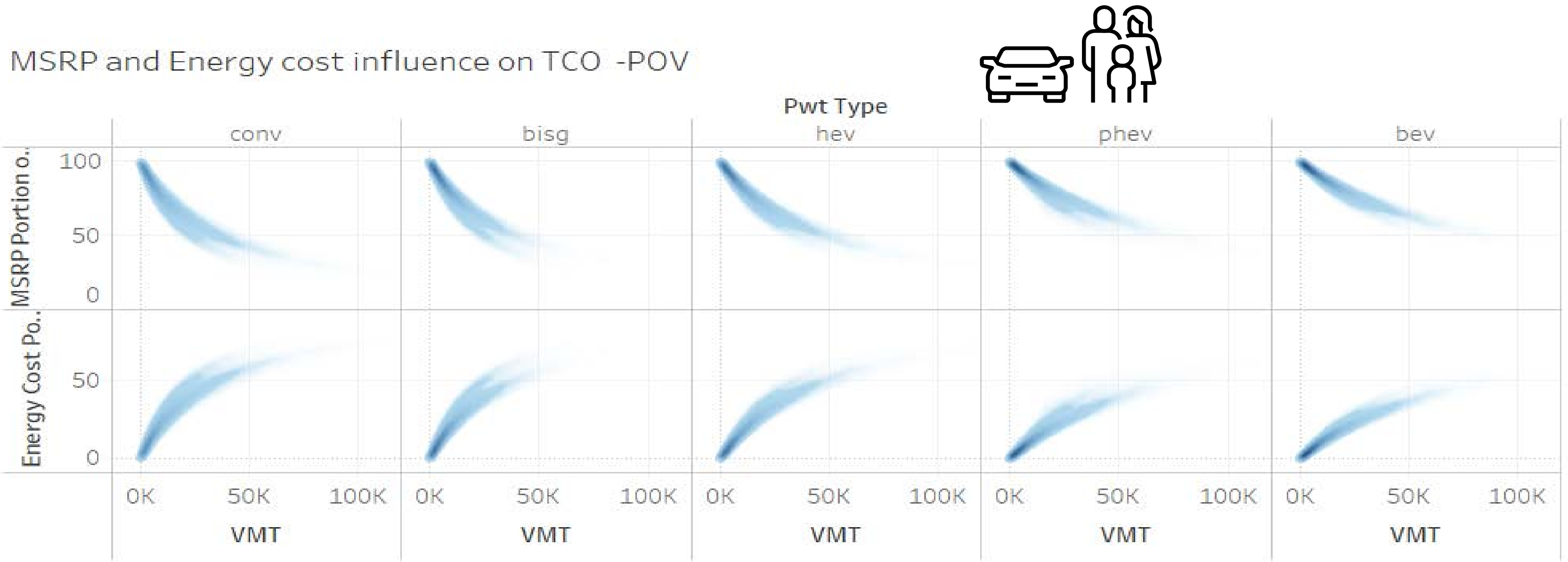


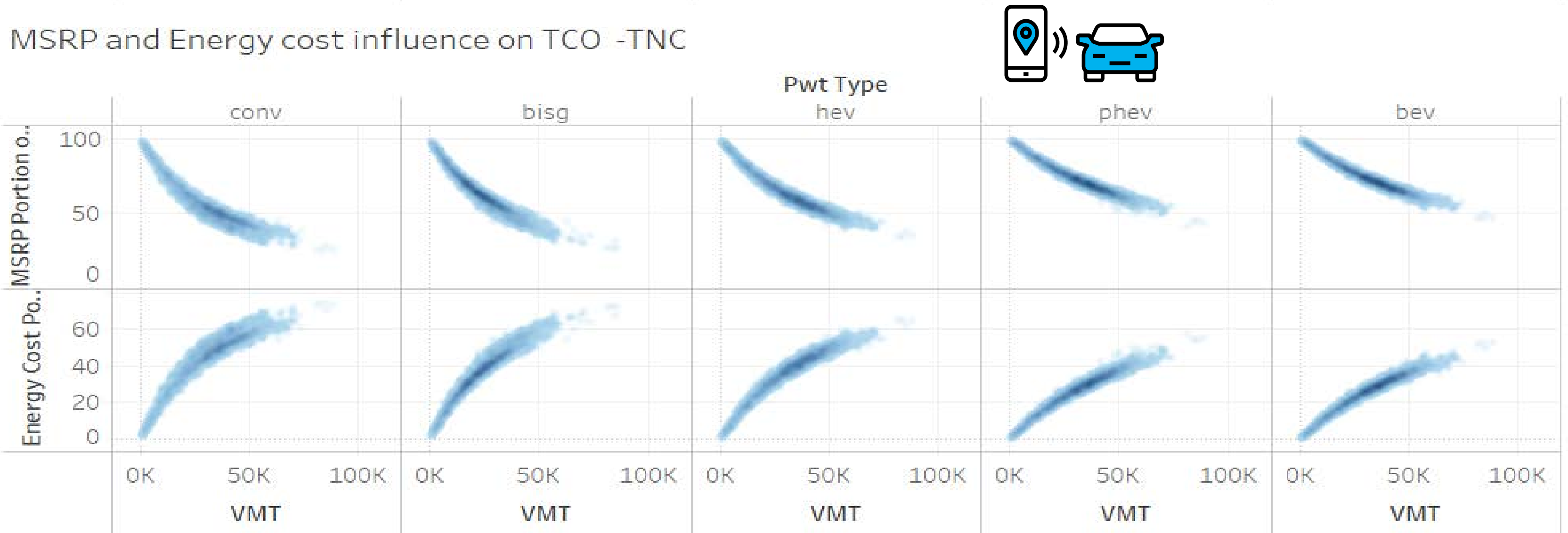
THE PURCHASE PRICE IS THE TCO PRIMARY DRIVER FOR PRIVATELY OWNED VEHICLES

Contribution of energy and purchase cost towards TCO (sum = 100%)

MSRP represents the biggest portion of the overall TCO

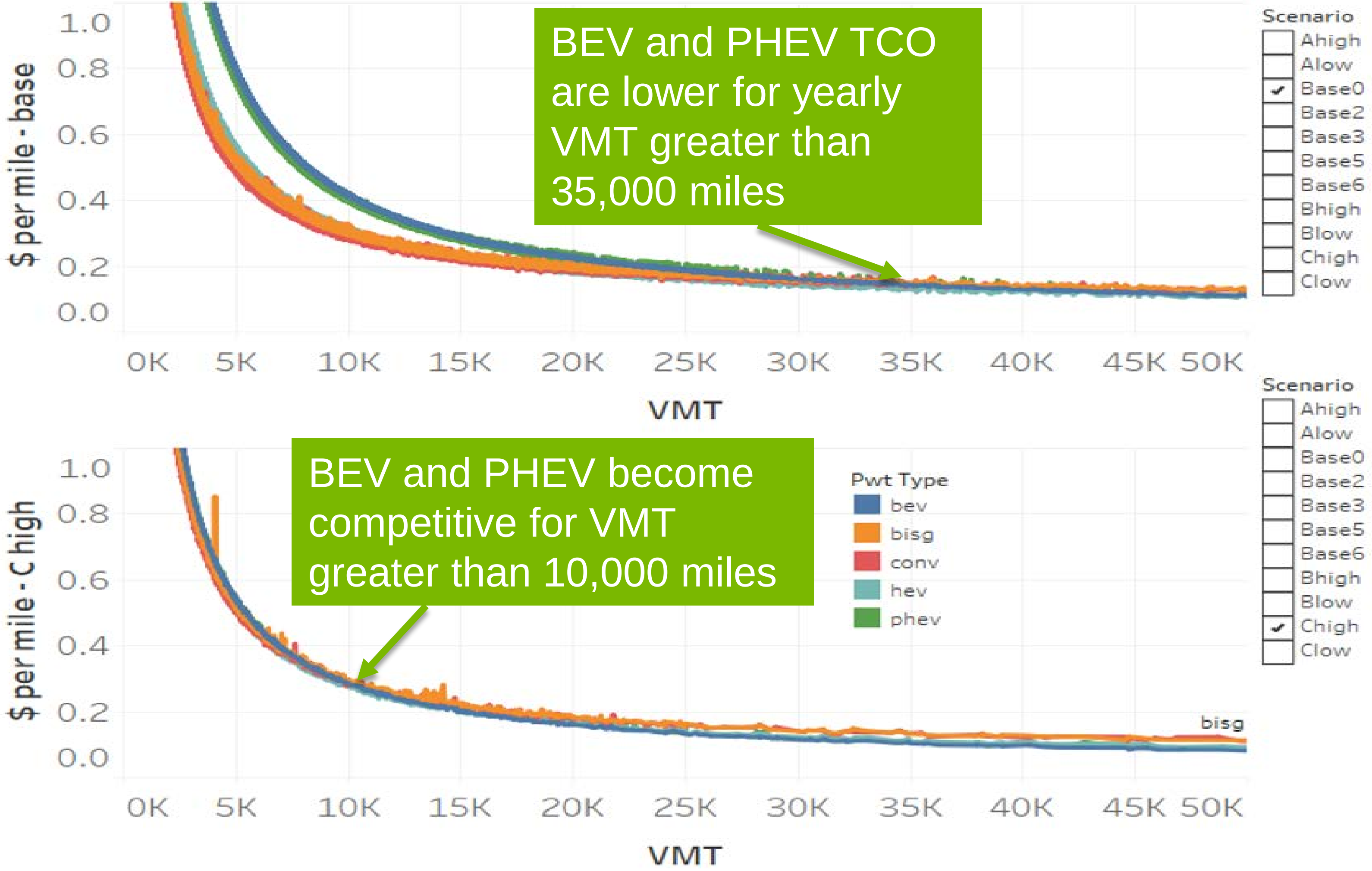
For TNC, the cost is more evenly split between MSRP and energy cost due to higher VMT





TCO IS PRIMARILY DRIVEN BY VMT AND FOR A GIVEN VMT, TCO FOR DIFFERENT POWERTRAINS CAN BE CLOSE

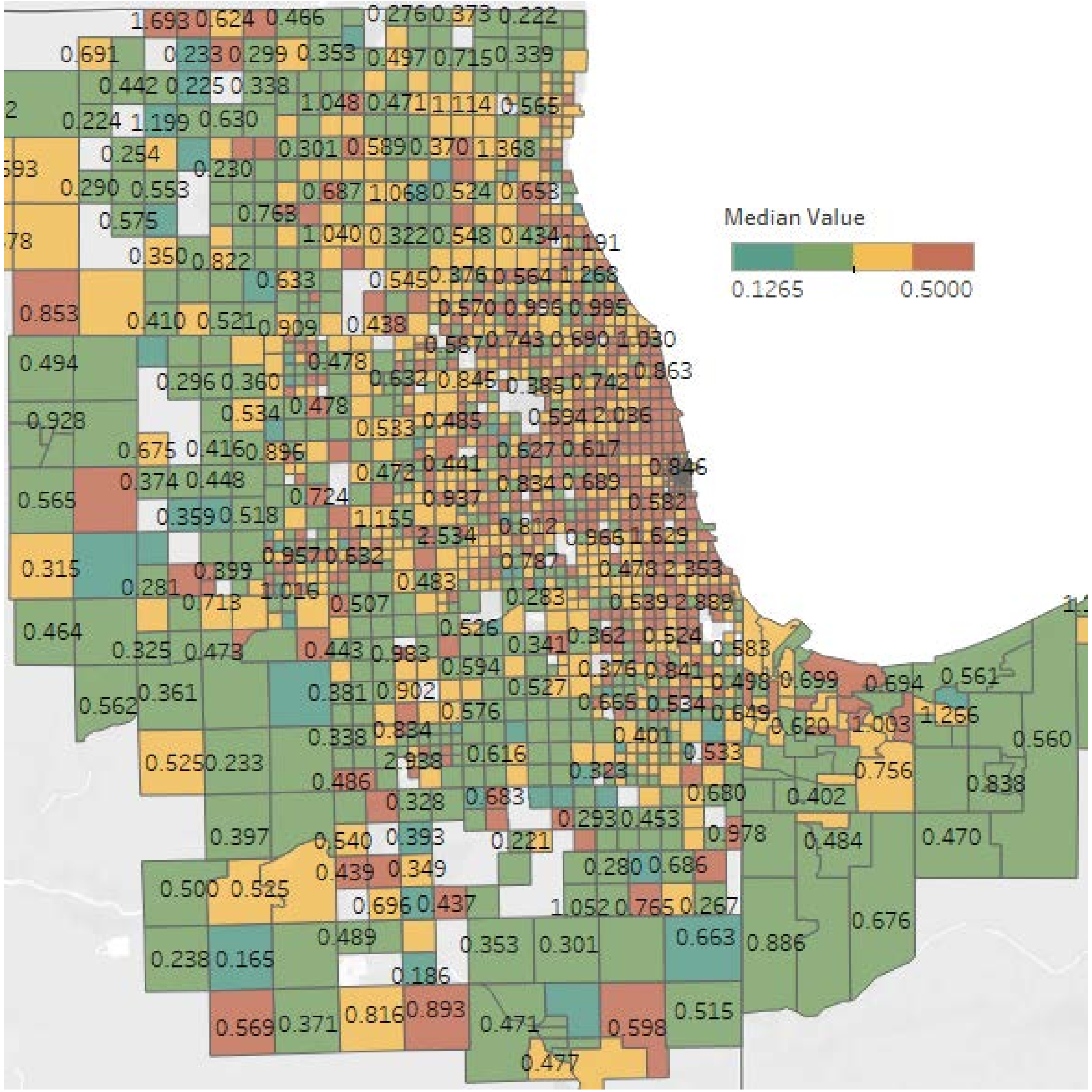
TCO as a function of VMT for each vehicle for the base and C high scenarios for all 5 powertrains



ANY METRIC CAN BE VISUALIZED BY ZONE THROUGHOUT THE METROPOLITAN AREA

Example: conventional powertrain TCO in scenario C high

- TCO is highest in the downtown area and decreases as households live further away from downtown
- Results for different powertrains and different scenarios show similar trends



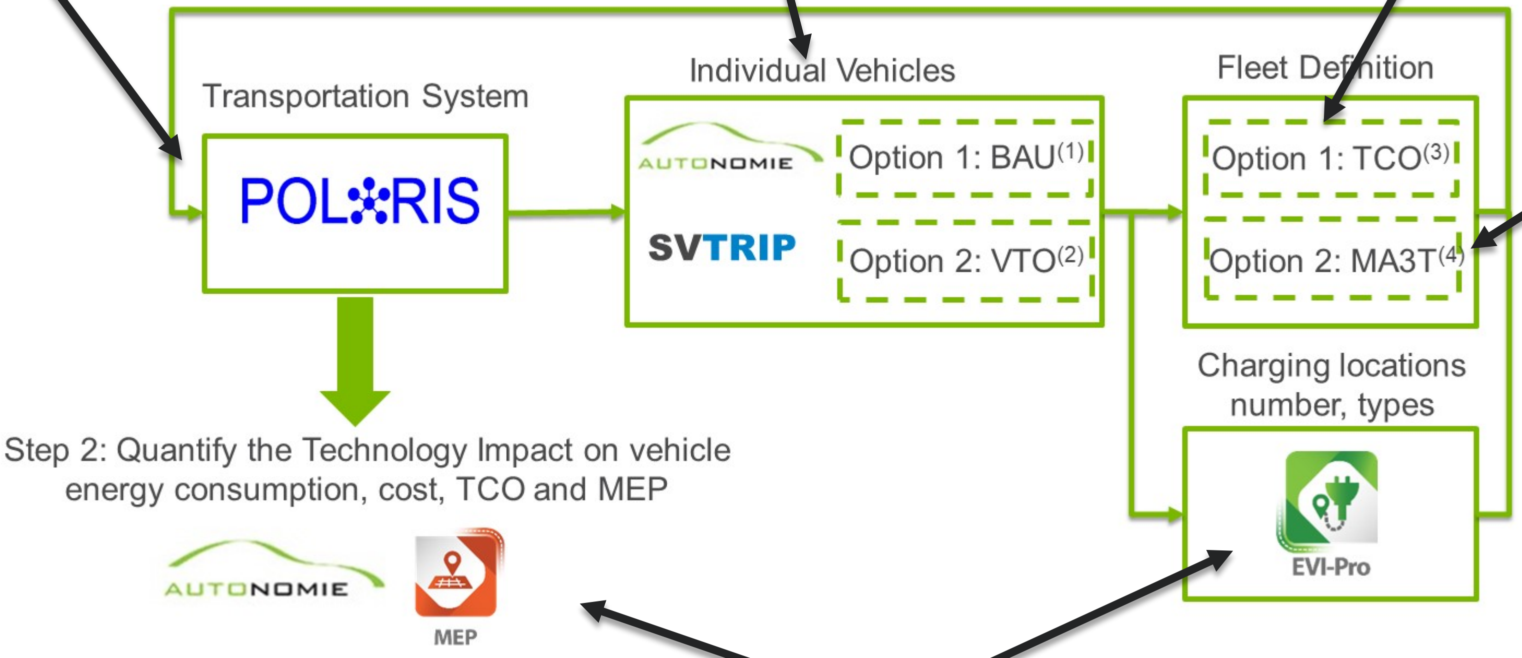
COLLABORATIONS

VAN023,
EEMS013

VTO Analysis
TCO Working
Group

Scenarios

Vehicle models



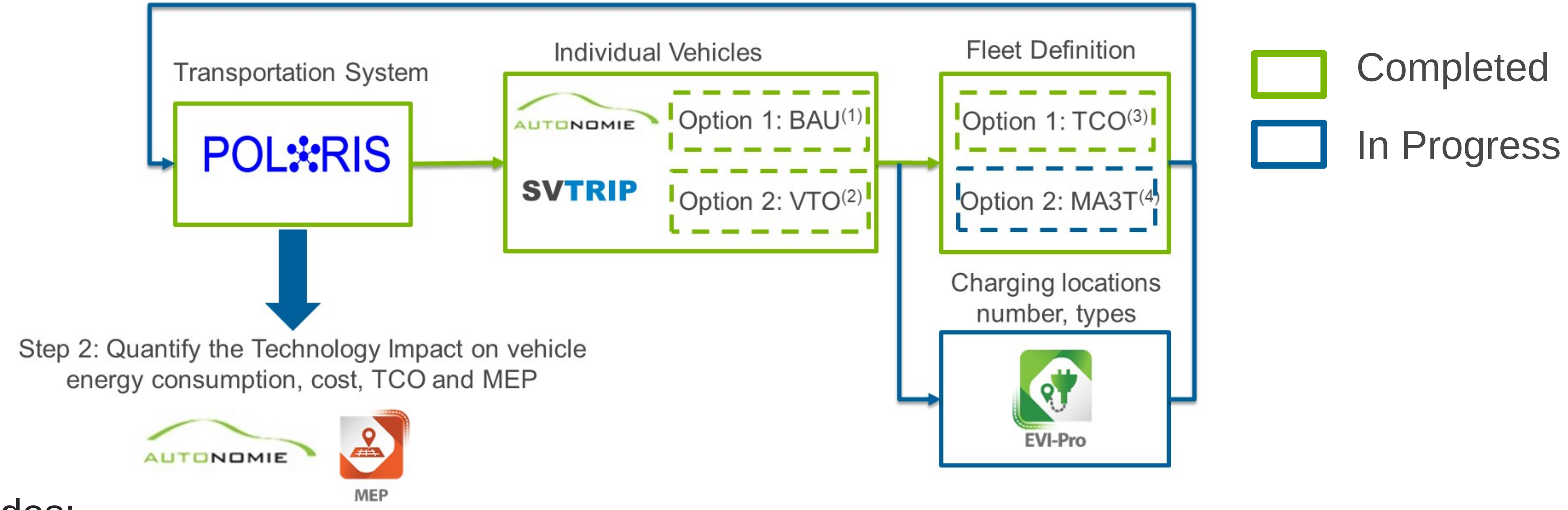
REMAINING CHALLENGES AND BARRIERS

- Very large amount of simulations need to be performed
  - For each POLARIS scenario, all the routes have to be simulated for each powertrain configurations
  - The process has to be repeated multiple times to close the loop with other tools (e.g., MA3T for fleet distribution, EVI-PRO for charging station locations and types)

  $\Rightarrow$ Need for high performance computing

  $\Rightarrow$ Need to automate process (both to perform and analyze the simulations)
- Expand the process for medium and heavy duty vehicles
- No market penetration tool currently includes all the vehicle classes (light to heavy duty), modes and automation levels

FUTURE RESEARCH



Next steps includes:

1. For the TCO based fleet
   1. Run all POLARIS scenarios with the new TCO fleets
   2. Quantify the impacts on charging station locations
   3. Rerun all POLARIS scenarios with the new TCO fleets and charging stations
   4. Quantify the impact on energy consumption, cost, TCO…
2. For the MA3T based fleet
   1. Reproduce steps above
3. Compare results with historical process

Any proposed future work is subject to change based on funding levels

SUMMARY

Using duty cycles from an entire transportation network provides a more granular and complete assessment of powertrain technologies

- Compared to using standardized duty cycles, using outputs from a large scale transportation model allows taking into consideration:
  - The realistic wide variability of duty cycle and VMT
  - The impact of decisions that people make under difference scenarios (travel decision behaviour and transportation mode choice)
- The high VMT threshold that is necessary to justify highly electrified vehicles today will go down significantly over time
- Based on TCO, while conventional powertrains may still make sense for many vehicles in the future, their share of VMT is much smaller.
- Assuming a high enough range to allow most VMT to be driven electrically (in this case 50 miles), PHEV powertrain provides the lowest cost of driving in many cases as it benefits from:
  - a relatively low cost of driving as it relies primarily on electricity
  - a relatively low purchase price as the battery size remains significantly smaller and hence cheaper than that of an electric vehicle

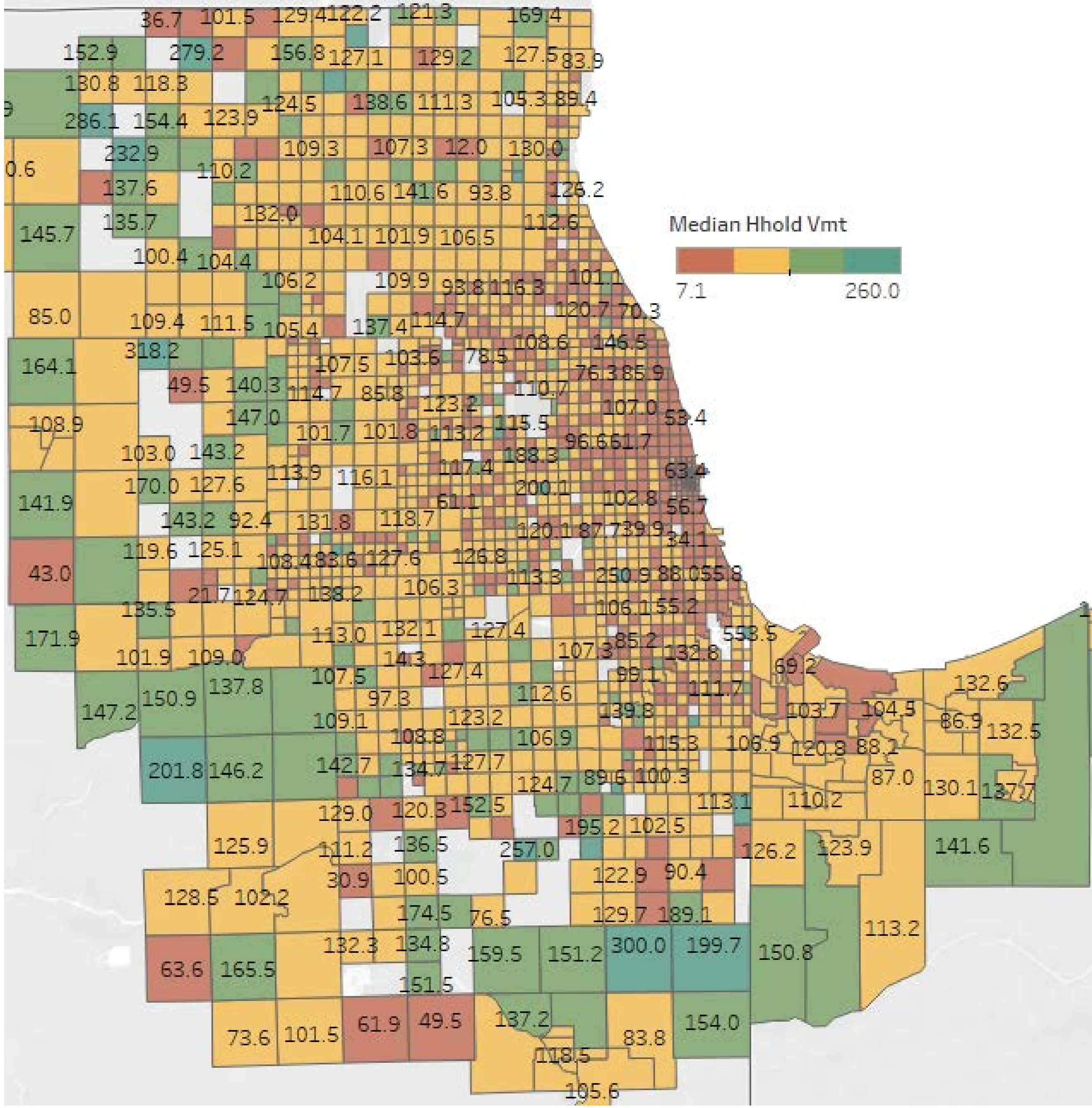
BACKUP SLIDES

TCO CALCULATION ASSUMPTIONS

- Cost for electricity, gasoline and diesel cost are derived from the 2019 IEA Energy Outlook and are expressed in 2018 dollar terms.
- Yearly VMT is calculated by scaling up daily VMT so that on average vehicles drive 14,000 miles per year. The distribution includes vehicles that have very high yearly VMT and vehicles that have very low yearly VMT.
- TCO is expressed in $/mile, includes the purchase price of the vehicle (MSRP) as well as the discounted energy cost over 12 years.
- A 4% discount rate is used for the energy cost calculation
- Other costs such as insurance and maintenance are not taken into account

DAILY HOUSEHOLD VMT FOR SCENARIO C HIGH (PRIVATELY OWNED VEHICLES)

VMT is lowest in the downtown area and increases as households live further away from downtown



AVERAGE TRIP LENGTH FOR SCENARIO C HIGH

Average trip length (miles) is lowest in the downtown area and increases as households live further away from downtown